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A SURVEY ON APPLICATION OF GAME THEORY IN MULTIPOINT TRANSMISSION OF HIGH SPEED NETWORK

ANNAPURNA V. K & C. VIDYA RAJ

Department of CS & E, NIEIT, Mysore, Karnataka, India

ABSTRACT

Current high-speed networks have to support applications which have no way of predicting their traffic requirements in advance but have stringent loss requirements and can tolerate variations in transfer delays. These performance characteristics mean that sources can be made to modify their data transfer rate according to network conditions. One way to set up multipoint–to-multipoint communication using one or more Virtual circuit channel in high speed network is by Shared Many to many ATM Reservation protocol. The main idea of the this scheme is that the resources for the requested service are reserved, and Resource Management (RM) cells are used as special control messages to control the link access. RM cells are sent periodically in order to be robust to cell losses. Congestion because of RM cells of non-cooperative nodes call for a game–theoretic approach to study both the behavior of such nodes, as well as their impact on the network performance. In this paper a brief overview of ATM, its RM cells and game theoretic terminologies are introduced.

KEYWORDS: Virtual Circuit Channel (VCC), Resource Management (RM), Nash Equilibrium, Price of Anarchy (POA), Price of Stability (POS), Potential Function

1. INTRODUCTION

Asynchronous Transfer mode (ATM) is high speed, high performance statistical multiplexing, cell switching and connection oriented technology that provides bandwidth on-demand for seamless transport of multimedia data in Local and Wider area environments.

Many multimedia applications are multicast, so it is important to provide scalable and efficient multipoint support for ATM. Multicasting results in better bandwidth utilization, decrease in network load, less host/router processing. The main purpose of multicasting is to provide efficient communication service for application that sends the same data to multiple recipients, without incurring network load. Main advantage of ATM is quality-of-service guarantees for multimedia communication, and to provide large aggregate bandwidth accompanying switch-based interconnection.

The ATM forum has defined three connection models for multicasting; point-to-point, point-to-multipoint and multipoint-to-multipoint connections. Of these, the multipoint-to-multipoint connection model is the most general, because it supports multiple senders and dynamic membership changes

Traffic management for multipoint connection is a complex problem, due to the presence of multiple senders with different traffic characteristics, multiple receivers with different QOS requirements, and different bottlenecks along the multipoint connection path.

Existing and available methods do not completely address the issues such as usage of bandwidth, high speed and reliable data transfer related to multicasting. Current high-speed networks have to support applications which have no way of predicting their traffic requirements in advance, but have stringent loss requirements and can tolerate variations in transfer delays. These performance characteristics mean that sources can be made to modify their data transfer rate according to network conditions.

One way to set up multipoint–to-multipoint communication using one or more VCC in high speed network is by Shared Many to many ATM Reservation protocol (SMART).This system is based on token. It uses transfer classes similar to ABT of ITU-T. Sender is allowed to transmit to group only after it has acquired a token. The main idea of the this scheme is that the resources for the requested service are reserved, and Resource Management (RM) cells are used as special control messages (GRANT and REQUEST messages) to control the link access.

RM cells are sent periodically in order to be robust to cell losses. Congestion because of RM cells of non-cooperative nodes call for a game–theoretic approach to study both the behavior of such nodes, as well as their impact on the network performance [1][2].

The rest of the paper is organized as follows; Section 2 gives a brief overview of RM cells. Section 3 introduces Game theory; Sections 4 describes how congestion created due to RM cells is analyzed through Game theoretic approach and finally Section 5 conclusion.

2. RESOURCE MANAGEMENT CELL

SMART uses the concept of data blocks as in ABT (of ITU-T), where a block is defined as series of data cells delineated by RM cells. The protocol supports one or several VCCs. There is one VCC for any number of end points. The set of v VCCs is called the multicast tree.

At UNI, an end system that participate in one multicast tree using SMART has to connect to v many-to-many VCC. The protocol guarantees that at most v data blocks can be interleaved on one Multicast tree. Resources for the requested services are reserved in both directions on all VC links of the tree until the connections are released. Resource management (RM) cells are used as special control messages. GRANT and REQUEST messages are RM cells to control the link access. These messages are associated with each VC connections.

When a system receives a GRANT message, this means that the sender of the GRANT is willing to receive data on this VC connection. If two GRANT messages coming from different directions cross each other on a link, a bias (initially negotiated among every two neighbors) is used to resolve the conflict. RM cell races are avoided by using a two bit-sequence number in the RM cells. Protocols Grant request in such a way that the reservations are respected and cell interleaving problem can never occur.

RM cells are sent periodically in order to be robust to cell losses. If this period is too large, the user access time to the multicast tree may increase significantly with the number of cell losses. However if the period is too small, RM cells are sent too often and may create some congestion in the network. A related issue is how to take into account the RM cells which are sent immediately when reserving resources for the RM cell flows.

RM cells are extracted and interpreted when received by a system implementing SMART. According to User Network Interface (UNI) & Network Network Interface (NNI) ATM cell format, payload type (PT) field with value 110

indicates RM cell. Cell Loss Priority bit is used to provide guidance to the network in the event of congestion to discard the cell (based on priority).

- Four control bits must be carried by each RM cell
  - Grant bit to indicate if the sender can receive data
  - Request bit to indicate if the sender has data to send
  - SN, a 2 bit sequence number to detect RM cell race conditions. The purpose of SN bits is to handle the loss or duplication of RM cells
- RM cells may be duplicated or lost but never reordered. The propagation time of an RM cell across a VC segment is dynamic.

One of the open issues which are yet not addressed by multipoint-to-multipoint is RM periodicity. Congestion because of RM cells of non cooperative nodes call for a game theoretic approach to study both the behavior of such nodes, as well as their impact on the network performance[3][4].

RM Cell Structure

SMART may follow ABT of ITU-T standard, but RM cell structure used in SMART is same as RM cell structure of ABR (of ATM).

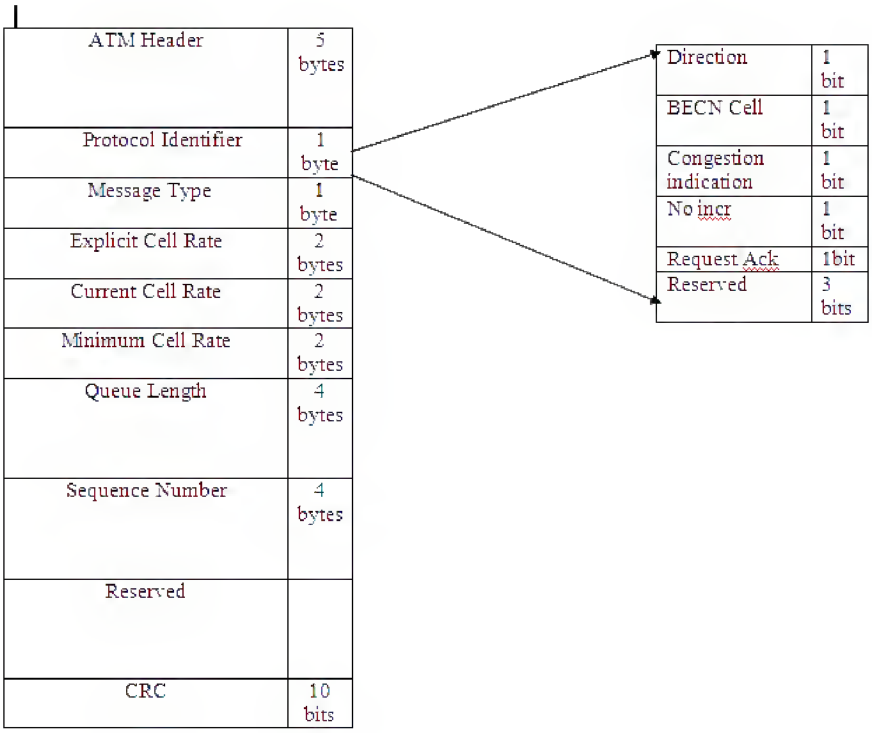

Figure 1: RM Cell Structure

3. GAME THEORY

Game Theory has been applied to a number of areas in computer networks such as congestion control, flow control and multicasting. Game theory is the science concerning the strategic interdependence among different

individuals. As the most important characteristic, each individual is in pursuit of maximal profit and benefits not only from its own action, but also from others.

A multimedia application in which contents are distributed from a source to multiple receivers is an example of multicasting. This application benefits receivers, but incurs cost. Assumption is that there are agents, located at various places in the network, who would derive some utility from receiving the content and that a cost is incurred each time the content is transmitted over a network link. The policy question is how these costs and benefits should be distributed; more specifically, which agents should receive the content, and how much should each agent pay?

The cost sharing algorithm does not know the individual utilities, and so users could lie about them.

A game in everyday sense –"A competitive activity in which players contend each other according to a set of rules". One of the main applications of game theory is in networks.

This approach looks at the network as a game whose players (or users) are the sources, routers and destinations and each player tries to maximize its payoff through its strategy (actions) set. The challenge in the game theoretic approach is to analyze selfish motives and actions by individual nodes and translate into desired results for the whole system.

Given the selfish nature of agents, the mechanism should be strategy proof, i.e., revealing *ui* (utilities) truthfully should be a dominant strategy. There are two other desirable features one would want in a cost-sharing mechanism: budget balance (the sum of the charges *pi* covers the total cost of transmitting the content) and efficiency (the total welfare is maximized).

Multicast games belong to class of congestion games. This class of games was defined by Rosenthal. Every congestion game has Nash equilibrium. Anshelevich and others introduced a measure of quality of the best Nash Equilibrium and Price of Stability (POS).

Nash Equilibrium

The action profile a^* in a strategic game with ordinal preferences is Nash Equilibrium if, for every player i and every action a_i of player i, a^* is at least as good according to player i's preferences as the action profiles (a_i, a^*_{-i}) in which player j chooses a_j^*. Equivalently for every player i,$\mu_i (a^*) \geq \mu_i(a_i, a_{-i}^*)$ for every action a_i of player i where μ_i is the payoff function representing player i's preferences.

Objective Function

Objective function is defined on outcome of the game that numerically expresses the social good or social cost of an outcome. Two important types are utilitarian and egalitarian functions, defined as the sum of the players' costs and maximum player cost (or minimum), respectively.

Price of Anarchy (POA)

$$\text{POA} = \frac{\textit{worst objective function value of an equilibrium of the game}}{\textit{optimal outcome}}$$

Price of Stability

$$\text{POS} = \frac{\textit{Best NASH Equilibrium}}{\textit{optimum network cost(social optimum)}}$$

Rosenthal has proved that for every congestion game, it is possible to define a potential function which decreases if a player improves its selfish cost. Best response dynamics in these games always lead to a set of paths that forms a Nash Equilibrium. It was further proved that multicast games always have a Nash Equilibrium. The number of iterations in best response dynamics achieving equilibrium can be exponential. Evolving at the Nash equilibrium state in multipoint-to-multipoint network is important and highly addressable due to the existence of non-cooperative end systems and intermediate nodes which may result in congestion and then by leading to cell loss for frequent transmission of RM cells in the network [5][6].

4. GAME THEORETIC APPROACH TO ANALYZE CONGESTION CREATED BY RM CELLS IN MULTIPOINT-TO-MULTIPOINT CONNECTION

Congestion games: Congestion games are defined by Monderer and Shapley as the cost of an edge e to a user iis$f_e(x) = c_e / x$, which depends only on edge e and the number of users x whose strategy contains e.

Proof: In a congestion game any sequence of selfish moves (improving moves because to improve cost) leads to a Nash equilibrium as each move decreases the potential function **Φ**, and hence lead to a stable state.

If s_i and $ś_i$ are two strategies and if $ś_i$ is better strategy, then player tries to shift from s_i to $ś_i$. This step of player i is called single strict Improvement step. In any congestion game, every sequence of strict improvement steps is necessarily finite, and terminates in a pure Nash Equilibrium. Thus, in particular, every congestion game has a pure strategy Nash Equilibrium.

This was proved using a potential function **Φ** defined as follows.

$\sum_{e \in E} \sum_{x=1}^{x_e} f_e(x)$.

If player i switches from strategy s_i to $ś_i$, leading from profiIe **s** to **ś** = **(s_{-i}, $ś_i$**) then

Φ(s) - (ś) =Ci(s) - Ci(ś)

(where Ci(s) is the total cost of player i given by **Ci(s)** = $\sum_{r \in s_i} d_r\left(n_r(s)\right)$

Where **r** is the resource, **d_r( )** is the cost function and **n_r(s)** is the congestion on resource **r**)

So every strict Improvement step must decrease the value of the potential function **Φ**(s) by at least 1 (the cost d_r(s) are all integers). A game in which such a function **Φ** exists is a potential game. Note that every improvement step is finite. Last profile **s** in any improvement sequence which cannot be further improved is, by definition, a pure Nash equilibrium.

To show that such a potential game has a deterministic Nash equilibrium, start from any state (strategy) S = (S_1, S_2......S_k) and consider a sequence of selfish moves (allowing players to change strategies to improve their costs). In a congestion game any sequence of such improving moves leads to a Nash equilibrium as each move decreases the potential function **Φ**, and hence must lead to a stable state.

Let x_e be defined as above with respect to S. Now the potential function of Equation in this is $\boldsymbol{\Phi(S)} = \sum_{e \in E} c_e H(x_e)$.According to the above argument, any improving deviation decreases **Φ** (S), and so a sequence of improving deviations by players must eventually result in a Nash equilibrium.

Consider $S^* = (S_1^*, S_2^*, \dots \dots \dots \dots S_k^*)$ defining the optimal centralized solution.

Let **OPT** $=\sum_{e\in S^*} c_e$ be the cost of this solution. Then $\Phi(S^*) \leq \sum_{e\in S^*}(c_e H(k))$, which is exactly H(k).OPT. Now start from S^* and follow a sequence of improving self-interested moves. This will result in a Nash equilibrium S with (S) ≤ Φ (S^*). Note that the potential value of any solution S is at least the total cost: $\Phi(S) \geq \sum_{e\in S^*} c_e$=**cost(S).** Therefore, there exists a Nash equilibrium with cost at most H(k). OPT, as desired. Even though cheap Nash equilibria exist, finding them is NP-complete [7][8].

5. CONCLUSIONS

Recently there has been a lot of research going in the area of multipoint-to-multipoint multicast communication and multimedia. A brief survey of ATM and its RM cell of Multicast transmission were introduced. In any multicast application, selfish routing of packets by agents takes place. This situation can be modeled using Game theoretic approach. Simple game theoretical terminologies were described. Anshelevich et. al showed that Rosenthal Potential can also be used to estimate the quality of equilibrium. In a congestion game any sequence of improving moves leads to a Nash equilibrium as each move decreases the potential function, and hence must lead to a stable state.

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